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Optimization Routine for Generating Medical Kits for Spaceflight Using the Integrated Medical Model

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Background

- The Integrated Medical Model (IMM) is a MATLAB model that provides probabilistic assessment of the medical risk associated with human spaceflight missions. Different simulations or profiles can be run in which input conditions regarding both mission characteristics and crew characteristics may vary.
- For each simulation, the IMM records the total medical events that occur and "treats" each event with resources drawn from import scripts.
- IMM outputs include Total Medical Events (TME), Crew Health Index (CHI), probability of Evacuation (pEVAC), and probability of Loss of Crew Life (pLOCL).
  - The Crew Health Index is determined by the amount of quality time lost (QTL).
- Previously, an optimization code was implemented in order to efficiently generate medical kits. The kits were optimized to have the greatest benefit possible, given a mass and/or volume constraint.

Project and Purpose

- This project is a continuation of the work done on the previous optimization routine. Instead of maximizing the benefit value of the medical kit given a mass and/or volume constraint, we are interested in minimizing the mass and/or volume of the kit, given a benefit constraint.
- This can be summarized as:

$$minimize \sum_{i=1}^{n} m_i x_i \ such\ that \sum_{i=1}^{n} b_i x_i \geq B$$

$$minimize \sum_{i=1}^{n} v_i x_i \ such\ that \sum_{i=1}^{n} b_i x_i \geq B$$

$$minimize \left(\sum_{i=1}^{n} m_i x_i \ and \sum_{i=1}^{n} v_i x_i \right) such\ that \sum_{i=1}^{n} b_i x_i \geq B$$

where m_i stands for item mass, v_i stands for item volume, b_i stands for item benefit, B stands for the benefit constraint, and x_i is a binary value indicating whether or not the item is included in the kit.

- The benefit constraint (*B*) is a CHI score, EVAC score, or LOCL score.
  - An 80% CHI score would mean that the kit attained a CHI score that was at least 80% of what it would be if a kit containing every resource from the maximum resource set were to be created.
- The goal is that this project will provide additional data that may help better inform choices about which resources would be the most beneficial to include in the medical kit on future missions.

Results

- A 6-crew, 14-day lunar mission was chosen for the simulation and run through the IMM for 100,000 trials.
- A built-in MATLAB solver, mixed-integer linear programming, was used for the optimization routine.
- Kits were generated in 10% increments ranging from 10%-100% of the benefit constraints. Conditions where mass alone was minimized, volume alone was minimized, and where mass and volume were minimized jointly were tested.

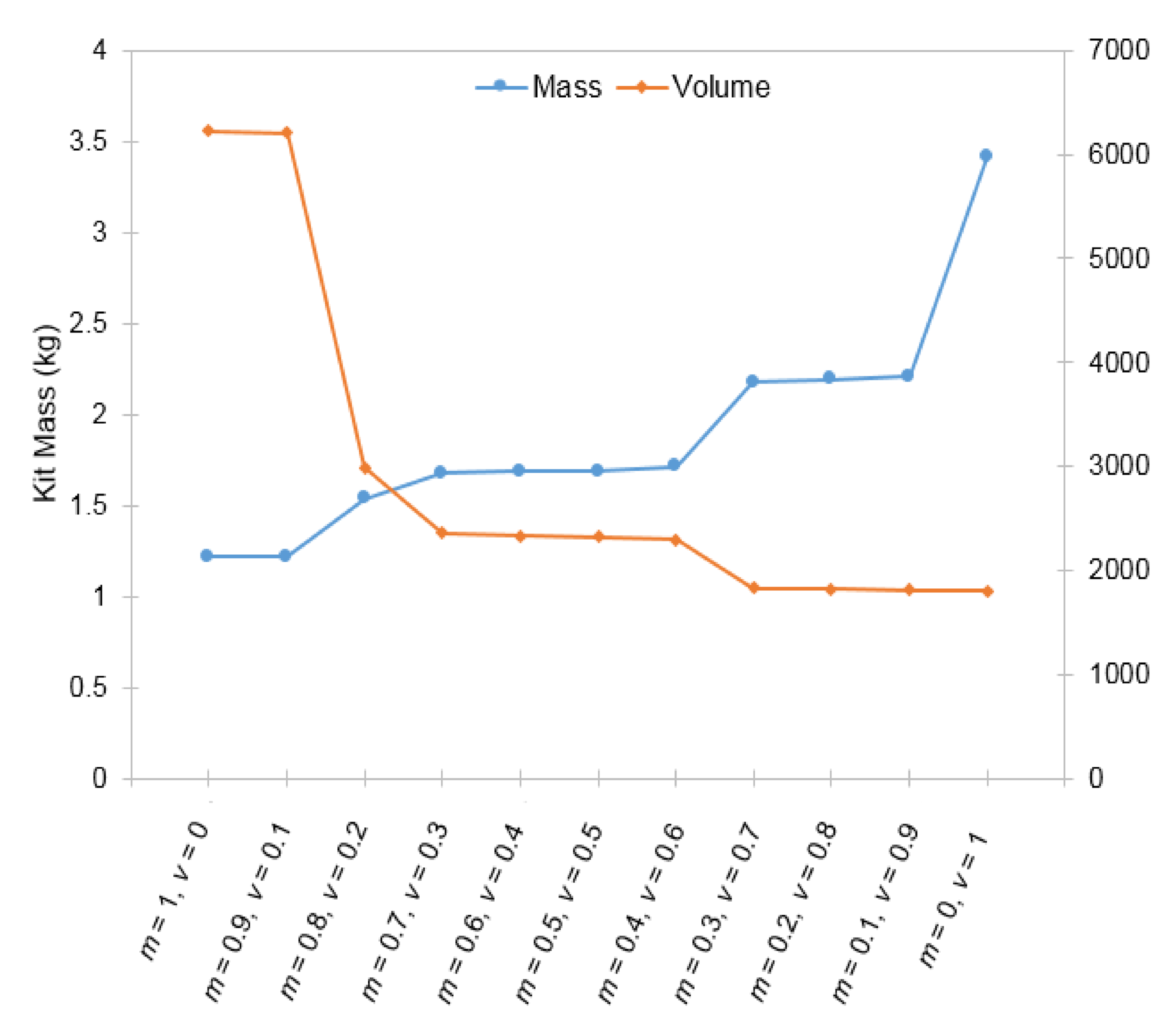

Figure 1. Optimized medical kits for a 90% CHI constraint. This figure shows the masses and volumes of the medical kits generated using the multi-objective knapsack solver. The x-axis shows the different scalarization values, with m representing the *mass_weight* and v representing the *volume_weight*.

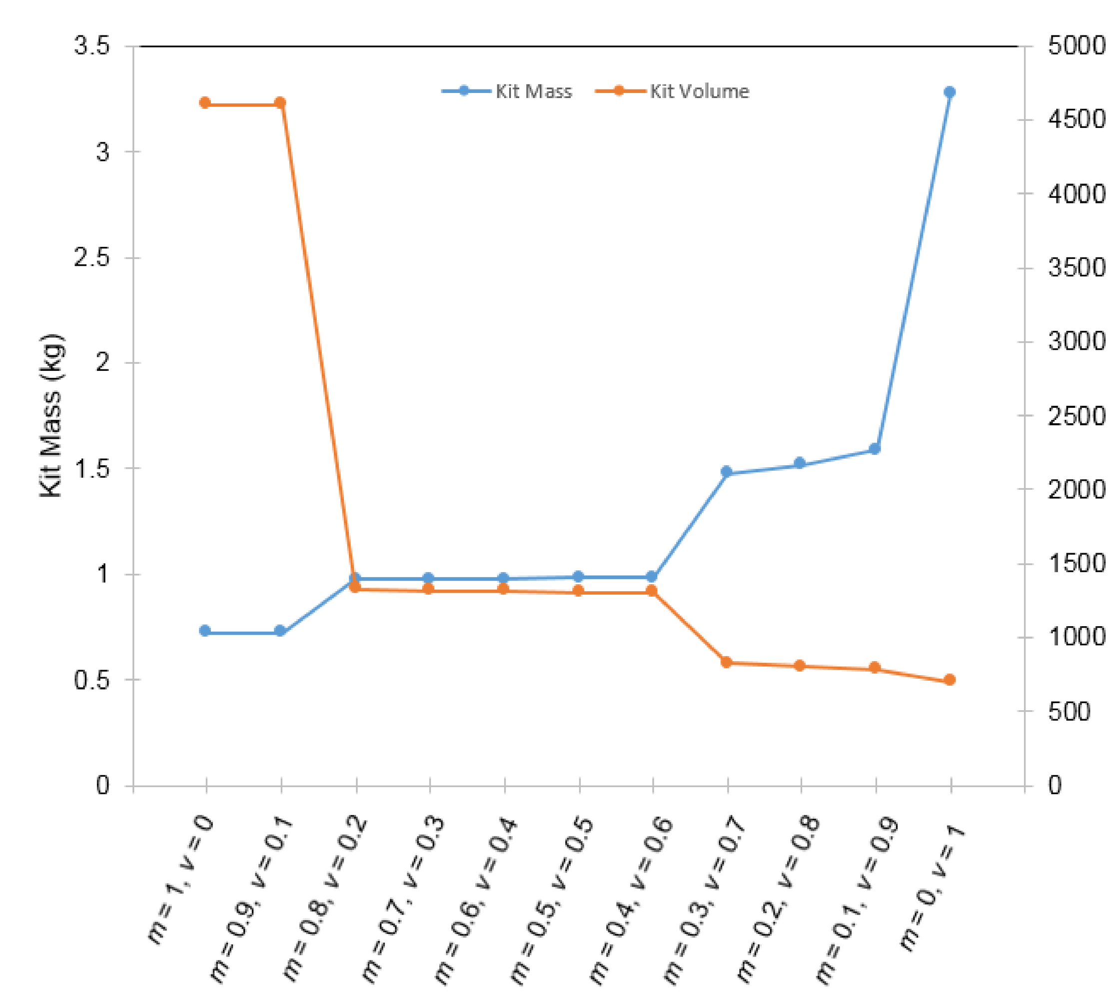

Figure 2. Optimized medical kits for an 80% EVAC constraint. This figure shows the masses and volumes of the medical kits generated using the multi-objective knapsack solver. The x-axis shows the different scalarization values, with m representing the *mass_weight* and v representing the *volume_weight*.

- As can be seen in Fig. 1 and 2, the mass is indeed the smallest when the mass alone is minimized, and the volume the smallest when volume is minimized.
- This sort of trend was what was hoped for, as it shows that the solver is capable of minimizing either mass alone, volume alone, or mass and volume jointly to produce some optimal medical kit.
- The mass and volume, then, can be weighted or scaled depending on whether mass or volume is of greater priority for a particular mission or vehicle.

Future Work

- Future work will include testing the routine using maximum resource sets generated from additional simulations or mission profiles (such as an ISS or Mars mission.) This will include looking into the benefit constraint more and seeing if our current method provides a good estimation.

Acknowledgements

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References

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